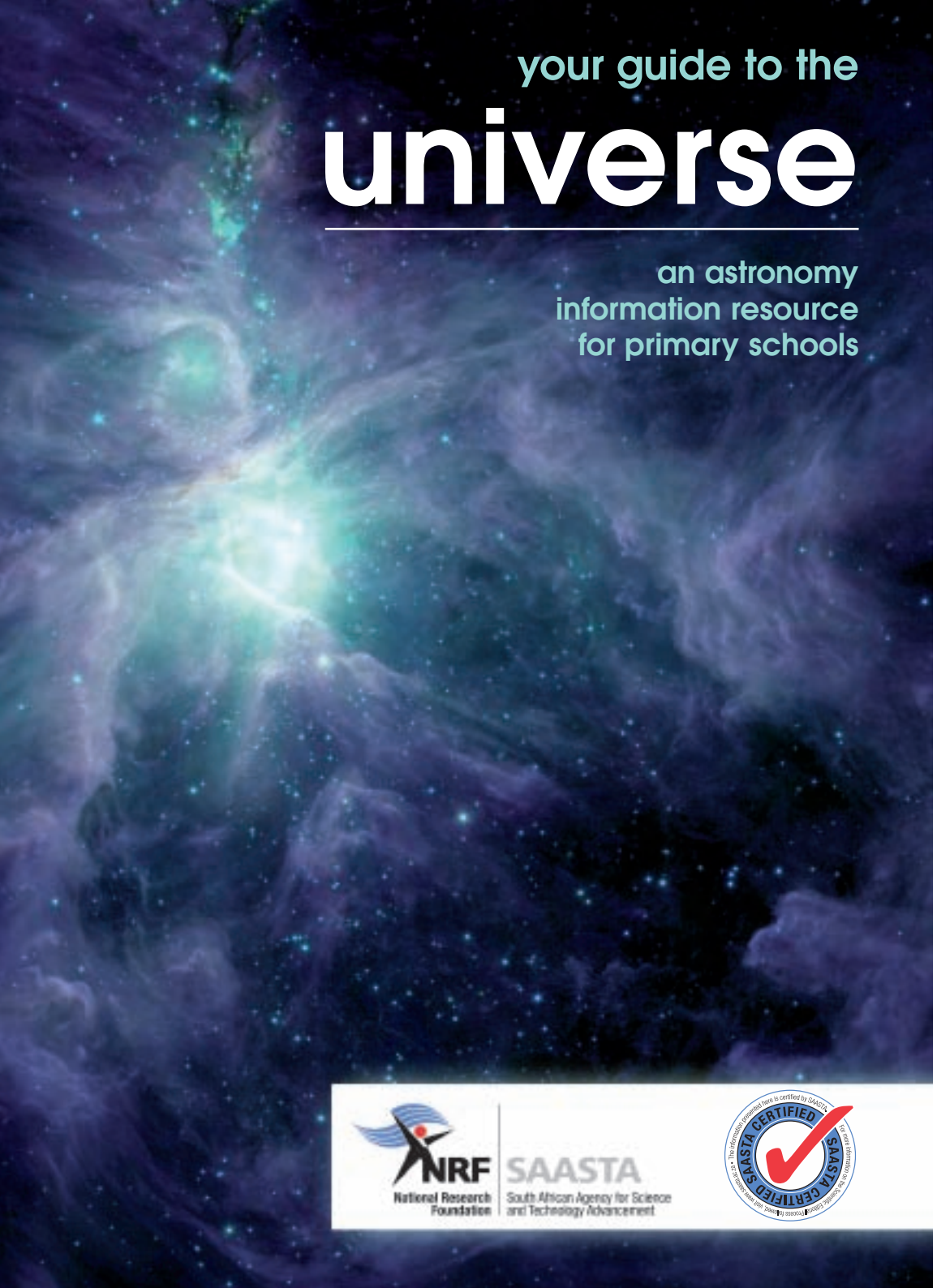
your guide to the
universe
an astronomy
information resource
for primary schools
NRF
National Research Foundation
SAASTA
South African Agency for Science and Technology Advancement
SAASTA CERTIFIED

The South African Agency for Science and Technology Advancement is funding this booklet as information resource for a national ASTRONOMY QUIZ. The material should be used by learners who prepare to take part in the Astronomy Quiz, together with further information and links published on the SAASTA website: www.saasta.ac.za

Various sources were used to compile the information contained in this booklet. They include:
Exploring our origins - SKA South Africa (www.ska.ac.za);
The Kingfisher Visual Fact Finder;
The Oxford Children's Encyclopedia;
www.saao.ac.za;
www.ska.ac.za;
www.hartrao.ac.za;
http://kids.msfc.nasa.gov/;
http://kidsastronomy.com;
www.womanastronomer.com;

For solar system information, visit the website: www.nineplanets.org.

NRF National Research Foundation | SAASTA South African Agency for Science and Technology Advancement

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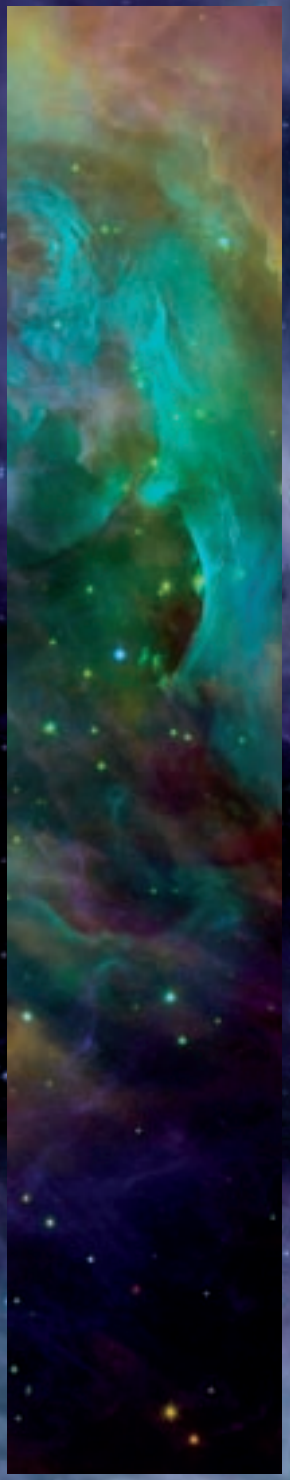


THE SOLAR SYSTEM

The Sun is an ordinary star, just like the ones you can see twinkling in the sky at night. But for us and all the creatures and plants that live on Earth, the Sun is very special.

The Sun is the centre of our Solar System. Orbiting around the Sun is its family of major planets, many with their own moons. There are also dwarf planets and thousands of other smaller objects such as asteroids, comets and meteor streams. The strong pull of the Sun's gravity holds it all together.

The Solar System is huge - over 12 000 million kilometres in diameter. It is shaped like an almost flat disk, as all the planets orbit in roughly the same plane. Pluto's orbit is tilted a little to the rest, and it also crosses just inside Neptune's orbit.

Our Sun is just one of about 100 000 million stars that make up our Milky Way galaxy. The Milky Way is one of many such star systems, each of which is called a galaxy. The Universe consists of about 100 000 million galaxies, each containing their own stars, planets and clouds of gas and dust, out of which stars and planets are born.

Day and night

Every day we see the Sun rise in the east and set in the west. For thousands of years, people thought that the Sun traveled around the Earth. Today we know that the Earth travels around the Sun.
As the Sun shines on the Earth, the rotation of the Earth around its own axis every 24 hours produces day and night. This rotation makes it seem like the Sun is moving across the sky.

The seasons

The movement of the Earth in an almost perfect circle around the Sun takes 365.26 days. Together, these days produce our year on Earth.

The seasons – Spring, Summer, Autumn and Winter – occur because the Earth's rotation axis is tilted at 23.5° to the plane of its orbit around the Sun. This means that for six months of the year from September through March the southern hemisphere is tilted towards the Sun, the tilt being biggest in December during mid-summer. In South Africa at this time we get lots of heat from the Sun because it passes nearly overhead at mid-day, and days are long. For the other six months from March through September, the southern hemisphere is tilted away from the Sun, the tilt being biggest in June, when we experience mid-winter. At this time we get much less heat from the Sun because at mid-day it is only about half-way up from the horizon, and days are short.

The Solar System consists of:

- ★ The Sun
- ★ Eight planets
- ★ Five dwarf planets
- ★ Many moons orbiting the planets and dwarf planets
- ★ Thousands of small Solar System bodies
- ★ Interplanetary dust

Image not to scale

WARNING!

Never look directly at the Sun. It is even more dangerous to look at the Sun through a pair of binoculars or a telescope. You will be blinded for life! Don't even look at the Sun through sunglasses.

Burning out

The Sun will burn out one day. It is predicted that when the Sun reaches the end of its life, it will swell up to a few hundred times its current size. It might just be big enough to engulf/ swallow the Earth. But this is no reason for concern, since it will take another 5 billion years for it to happen!

The Sun

The Sun's heat and light provide the energy for life to exist on Earth. The Sun is a giant ball of extremely hot hydrogen and helium gases, nearly 150 million kilometres away. It is gigantic compared to the Earth. If you think of the Sun as a football, Earth would be the size of the head of a match. You could fit about 100 Earths side by side across the Sun and it could hold more than a million Earths inside its volume. Only because the Sun is so far away does it appear to be the same size in the sky as our our Moon, which is actually much smaller than our Earth, but much closer to Earth than the Sun is.

The Sun is extremely hot. On the surface of the Sun the temperature is nearly 6000 degrees Celsius, but at the centre it is about 16 million degrees. In this hot, dense core of the Sun hydrogen atoms get squashed into each other to produce helium atoms. This releases enormous amounts of energy, which escapes as heat and light. The Sun also produces X-rays and ultraviolet rays that are harmful to life, but most of these rays get soaked up by the Earth's atmosphere and do not harm us.

Scientific research has shown that the Sun and planets formed about 4.6 billion years ago out of a big cloud of gas and dust. All the planets, asteroids and comets that orbit the Sun, including the Earth, formed at the same time. Sometimes dark spots, called sunspots, appear on the surface of the Sun. These are cooler areas and are produced by strong magnetic fields.

THE PLANETS

Although all the planets of our Solar System were formed at the same time and from the same cloud of gas and dust, there are great differences between them.

The four inner terrestrial (Earth-like) planets are Mercury, Venus, Earth and Mars, and are mainly made of rock and metal. Beyond lie Jupiter, Saturn, Uranus and Neptune, which are giant, gas planets. Distant dwarf planets do not fit into any of these groups. They are probably made of ice and rock.

Remember the planets

The planets are named after ancient Greek and Roman gods. An easy way to remember these names is to remember the sentence: "Mother very enthusiastically made a jelly sandwich under no protest" or "Many Very Elderly Men Just Sleep Under Newspapers" or "My Very Excellent Mother Just Served Us Noodles" or "Mary's Violet Eyes Make John Stay Up Nights".

Beginning with Mercury, the closest to the Sun, and ending with Neptune, the farthest from the Sun, the sentence gives you clues to the order of the planets: Mercury, Venus, Earth, Mars, Asteroids, Jupiter, Saturn, Uranus, Neptune.

Dwarf Planets

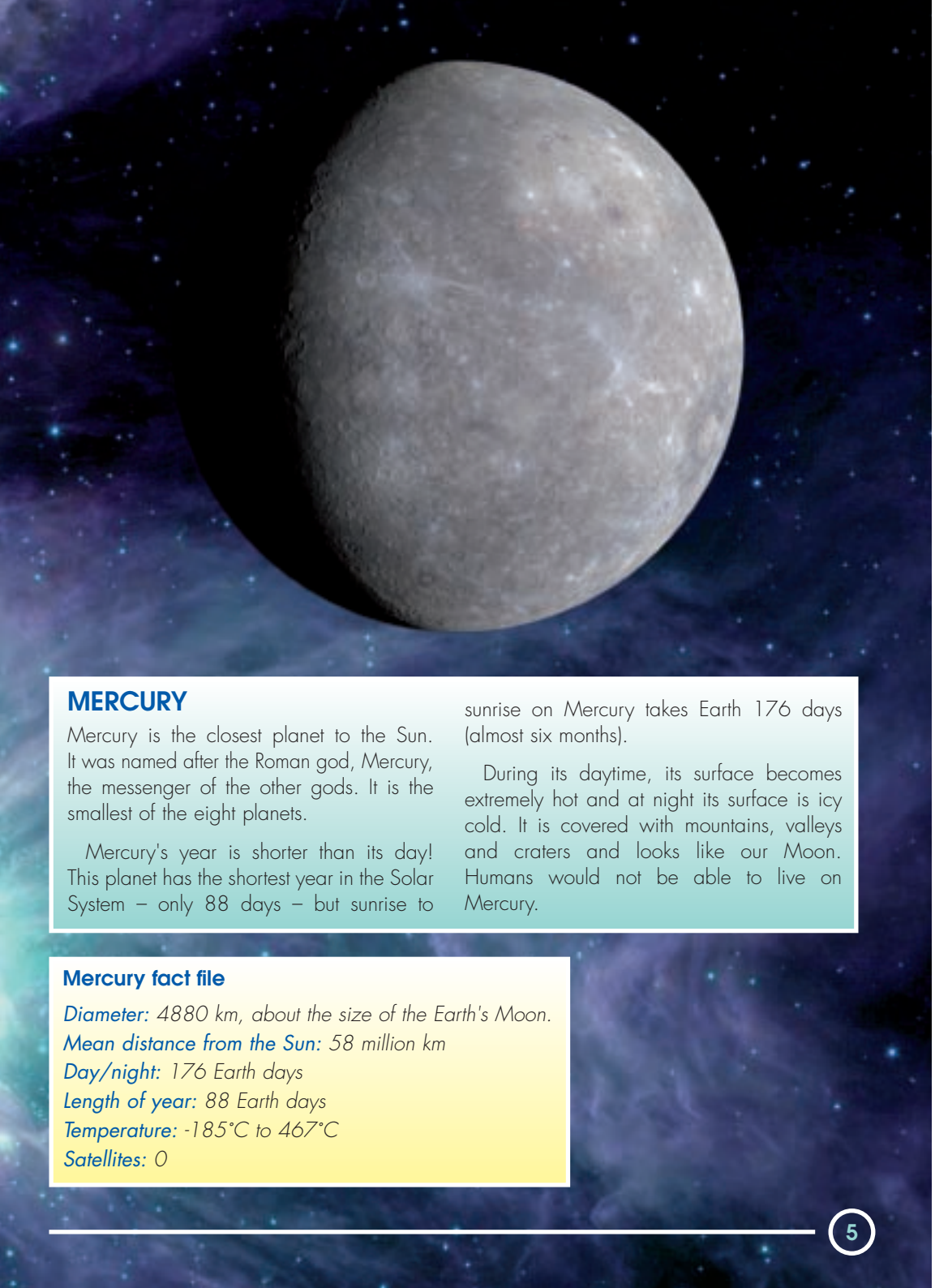
Pluto, which used to be the ninth planet, and many other similar sized bodies lie beyond Neptune. In 2003, Eris was discovered, which is larger than Pluto. In 2006 the International Astronomical Union created a new category of solar system objects called "dwarf planets" that is distinct from "planets". Pluto was reclassified as a dwarf planet, Eris received dwarf planet status and Ceres, the largest of the asteroids that orbit mainly between Mars and Jupiter, was also classified as a dwarf planet.

Another two objects lying beyond Neptune, called Haumea and Makemake, have also been classified as dwarf planets.There could be about 200 objects, in this region called the Kuiper Belt, which may be big enough to be called dwarf planets. It is likely that there will be many more dwarf planets in the future as the sky is more fully explored. All of the dwarf planets that we know of so far are smaller than our Moon.

The definition of a "dwarf planet" is: a celestial body that

a. is in orbit around the Sun,
b. has sufficient mass to become nearly round in shape,
c. has not cleared its orbit of other celestial bodies, and
d. is not a satellite (or moon) of another celestial body.

The celestial bodies that are not massive enough to be rounded by their own gravity are called "small solar system bodies".



MERCURY

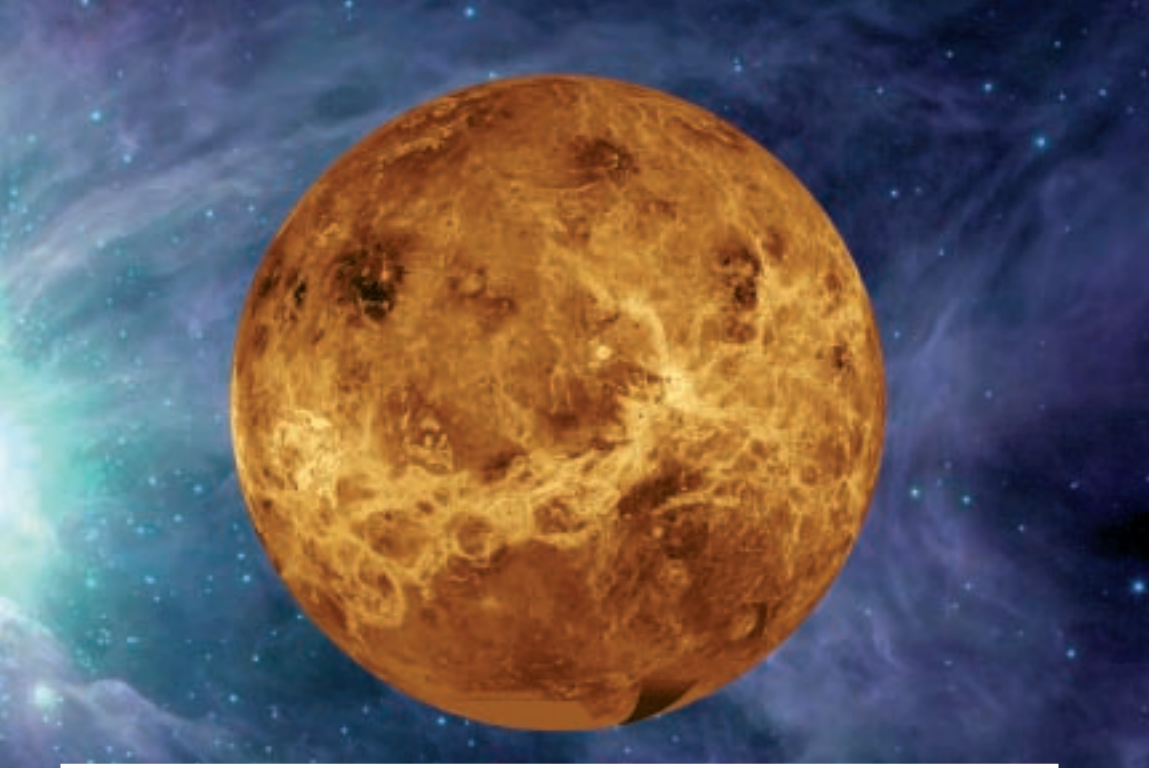
Mercury is the closest planet to the Sun. It was named after the Roman god, Mercury, the messenger of the other gods. It is the smallest of the eight planets.

Mercury's year is shorter than its day! This planet has the shortest year in the Solar System – only 88 days – but sunrise to sunrise on Mercury takes Earth 176 days (almost six months).

During its daytime, its surface becomes extremely hot and at night its surface is icy cold. It is covered with mountains, valleys and craters and looks like our Moon. Humans would not be able to live on Mercury.

Mercury fact file

Diameter: *4880 km, about the size of the Earth's Moon.*
Mean distance from the Sun: *58 million km*
Day/night: *176 Earth days*
Length of year: *88 Earth days*
Temperature: *-185°C to 467°C*
Satellites: *0*



VENUS

Venus is the hottest planet in the Solar System. It was named after the Roman goddess of love and beauty because it looks like a gleaming gem in the sky. But in fact, the planet is a hot, rocky waste under an atmosphere almost entirely made up of carbon dioxide. Its thick atmosphere holds in the Sun's heat.

Venus and the Earth are almost the same size. Venus is also the planet that approaches closest to Earth.

The surface of Venus is completely hidden by dense, white clouds. However, we know what its surface looks like thanks to information we got from space radar, and two spacecraft that landed on its surface and took pictures. There are high mountains, craters and volcanoes on Venus.

Venus is unusual because it rotates in the opposite direction from all the other planets.

Venus fact file

Diameter: *12 104 km, about 0,8 times the size of the Earth*
Mean distance from the Sun: *108 million km*
Day/night: *117 Earth days*
Length of year: *225 Earth days*
Temperature: *460°C on average*
Satellites: *0*

EARTH

Our planet is the largest of the rocky (terrestrial = Earth-like) planets. The word "earth" is Old English and comes from German. As far as we know, the Earth is unique in the Solar System for two reasons: it has liquid water on its surface and it supports life. If you look at Earth from space it seems like a blue and white ball. Before the time of space travel and satellite images, people were not able to see Earth like this. Without pictures it is hard to imagine that the Earth is a ball-shaped planet traveling through space.

Earth is almost round like a ball, but not quite. It bulges at the middle (Equator) and flattens at the Poles. This shape is called a spheroid.

The time its takes the Earth to complete one orbit around the Sun is called a year. A year is 365 days, 5 hours, 48 minutes and 46 seconds long. We divide the year into 365 days, but every fourth year, a leap year, has 366 days to make up the extra time. In a leap year there are 29 days in February.

Earth fact file

Diameter: *12 756 km*
Mean distance from the Sun: *150 million km*
Day/night: *24 hours*
Length of year: *365 Earth days 5 hours*
Temperature: *maximum 58°C; minimum -89°C*
Satellites: *1 – the Moon*

Mars fact file

Diameter: 6 794 km, about half that of the Earth
Mean distance from the Sun: 228 million km
Day/night: 24 hours 37 minutes
Length of year: 687 Earth days
Temperature: -133°C to +27°C
Satellites: 2

Mars

Mars was named after the Roman god of war and agriculture. It shines very brightly when closest to the Earth, but at other times its orbit takes it so far away that it is much dimmer, like a star. It has a orange-red colour and so is often called the Red Planet.

Mars is the only planet selected for possible exploration by humans because conditions there are more like those on Earth than on any of the other planets. There is evidence that Mars once had rivers, streams, lakes, and even an ocean. Today the only water on Mars is either frozen in its polar caps, or underground.

In recent years, unmanned spacecraft called space probes have landed on Mars. The probes, sent to Mars by the United States of America, performed experiments on the surface and atmosphere. The dirt was found to contain clay rich in iron.

Mars has many craters and mountains. The highest mountain peak and some of the deepest valleys in the Solar System are found on Mars.

Mars has two moons, called Deimos and Phobos. They might be the remnants of a larger moon that broke up many millions of years ago, but they could well be asteroids that have been captured by Mars.

Asteroids

Asteroids are minor planets. Many of them are found in a belt between Mars and Jupiter. Being small, they look like pinpoints of light in the night sky. Over 3000 have been discovered, but you need not know all their names! The largest known is Ceres, which has a diameter of 1000 km. Smaller asteroids are not round, but have irregular shapes, like potatoes.

Asteroids are bits of rock. They are left over material from the time our Sun its and planets were formed.

Today about 1000 asteroids orbit near the Earth. Asteroids have on occasion collided with the Earth to form very large impact craters. The largest in the world can be found around Vredefort in the Free State, 100km south of Johannesburg.It occurred 2 billion years ago. The crater was much bigger than the 85km wide ring of hills that we now see around Vredefort. It has been worn away by erosion over time. Tswaing, 40km north of Tshwane, is a 1 km wide crater made just 200 000 years ago by an asteroid the size of a building. Have you visited either of them?

The Tswaing meteor crater. *Photo: M J Gaylard*

Jupiter fact file

Diameter: *142 800 km*
Mean distance from the Sun: *778 million km*
Day/night:
9 hours 50 minutes
Length of year:
4330 Earth days
= 11.9 Earth years
Temperature: *-150°C*
Satellites: *63 discovered by 2009*

Jupiter

In mythology, Jupiter (known as Zeus in Greece) was the king of the gods. Jupiter is by far the largest planet in the Solar System. It is so big that all the other planets can be squeezed inside it.

Jupiter spins so fast that a day on the planet lasts less than 10 hours.

Jupiter is made up of about 90% hydrogen and 10% helium, with traces of other elements. In its centre these gases are compressed to a very hot liquid. The stripes on its surface are cloud markings. Large areas of swirling gases can be found in Jupiter' atmosphere. The largest of these is called the Great Red Spot. Scientists have been watching this giant storm rage for several hundred years. Bolts of lightning have also been seen in Jupiter's atmosphere.

Photographs taken by spacecraft have shown thin, dark rings around Jupiter.

By 2003, 63 moons had been found orbiting Jupiter. The four largest moons were discovered by Galileo Galilei with his primitive telescope in 1610. They are Io, Europa, Ganymede and Callisto. There are active volcanoes on Io, which orbits Jupiter in a day. Europa is a ball of ice. Ganymede is the largest satellite in the Solar System.

Saturn

Saturn gets its name from the Roman god of agriculture. It is the second largest planet in the Solar System. Saturn is known as the ringed planet. We now know that all four giant planets have rings, but Saturn's are by far the most impressive.

Saturn has over 1000 rings, made of ice and dust. The ice particles in the rings range from pebble-size to house size. Scientists think these rings could be the remains of a small moon or moons that were smashed by comets or meteorites. Saturn's gravity could then have pulled the particles into rings.

Saturn is a very large gas planet which spins so quickly that its equator bulges outward and the top and bottom are flattened out noticeably. The white spots on Saturn's surface are powerful storms.

Saturn has a lot of moons (61 discovered as of 2009) of which 52 have been named. Titan is Saturn's biggest moon and it has a thick nitrogen atmosphere.

In January 2005, the Huygens space craft plunged through Titan's atmosphere and sent back to Earth the first images of this, the furthest place from Earth a spacecraft has ever landed. Scientists think that conditions on Titan are like those on Earth 4.6 billion years ago.

The mysteries of Saturn have always puzzled researchers. They wonder why Saturn, a gas-giant made up primarily of hydrogen and helium, releases more energy than it absorbs from faint sunlight. Titan is also the only moon in the solar system to have a dense atmosphere, one even thicker than Earth's.

Saturn fact file

Diameter: 120 000 km
Mean distance from the Sun: 1429 million km
Day/night: 10 hours 14 minutes
Length of year: 10759 Earth days = 29.5 Earth years
Temperature: -170°C
Satellites: 61 (as of 2009)

A	S	U	E	H	T	E	M	O	R	P	B	N	A	P
M	U	N	D	I	L	F	A	R	I	C	D	E	G	F
I	T	A	I	E	N	C	E	L	A	D	U	S	I	H
M	T	R	J	A	N	U	S	T	P	H	O	E	B	E
A	U	O	I	K	L	M	L	H	E	L	E	M	E	P
S	N	D	R	J	N	A	P	Q	T	H	R	Y	M	I
O	G	N	A	R	S	A	K	S	U	T	V	M	H	M
U	B	A	Q	A	N	R	A	I	S	W	X	I	Y	E
O	S	P	Y	L	A	C	L	C	V	K	D	R	P	T
T	I	T	A	N	S	Y	B	D	Z	I	A	E	E	H
S	F	H	G	Y	S	T	I	U	H	I	U	D	R	E
E	J	L	H	K	O	O	O	M	N	L	X	Q	I	U
L	P	T	R	Q	N	V	R	H	E	A	W	Y	O	S
E	E	A	C	E	R	R	I	A	P	O	B	D	N	E
T	A	R	V	O	S	Z	X	P	A	A	L	I	A	Q

Here are the names of 30 of Saturn's moons. Try and find them in this word puzzle:

Mimas
Hyperion
Epimetheus
Ymir
Thrym
Enceladus
Iapetus
Janus
Paaliaq
Skadi
Tethys
Pan
Calypso
Siarnaq
Mundilfari
Dione
Atlas
Telesto
Tarvos
Erriapo
Rhea
Prometheus
Helene
Kiviuq
Albiorix
Titan
Pandora
Phoebe
Ijiraq
Suttung

Uranus fact file

Diameter: 51 000 km
Mean distance from the Sun: 2870 million km
Day/night: 17 hours 14 minutes
Length of year: 30685 Earth days = 84 Earth years
Temperature: -200°C
Satellites: 27 discovered by 2009

Uranus

In mythology, Uranus was the lord of the skies and the husband of Earth. Apart from the fact that it orbits the Sun on its side and has satellites, little was known about this planet until the space probe Voyager 2 flew past it 20 years ago.

Uranus' odd tilt may be the result of a powerful crash with another large object soon after it had formed. The effect is that each pole spends about 40 years in constant summer sunlight, and then another 40 years in winter darkness.

Uranus has many dark rings - nine major ones and many other faint ones. The planet itself is made up mainly of hydrogen and helium gases. It has a rocky core and there may be an ocean of water/ammonia beneath its clouds.

Uranus has at least 27 moons, most named after characters in Shakespeare plays. The largest ones are Titania, Ariel and Miranda.

Neptune fact file

Diameter: 49 500 km
Mean distance from the Sun: 4504 million km
Day/night:
17 hours 6 minutes
Length of year:
60190 Earth days
= 165 Earth years
Temperature: -210°C
Satellites: 13 discovered by 2009

Neptune

Neptune was named after the Roman god of water and the ocean. Its bright blue atmosphere, coloured by methane, might look calm, but Voyager 2 discovered winds of up to 2000 km/h ripping through its atmosphere - the fiercest winds in the Solar System. The winds travel in a different direction to the planet's spin.

Neptune has a large storm raging on its surface, much like Jupiter. It is called the Great Dark Spot. This storm, discovered by Voyager 2, is large enough to contain the Earth.

Neptune has four rings surrounding it. It is the outermost giant planet. It is the outermost planet.

It also has at least thirteen moons, six of them discovered by Voyager 2. Many more may still be discovered. The largest of Neptune's moons, Triton orbits Neptune backwards.

Pluto fact file

Diameter: *2 300 km*
Mean distance from the Sun: *5900 million km*
Day/night: *6 Earth days and 9 hours*
Length of year: *90550 Earth days = 248 Earth years*
Temperature: *-230°C*
Satellites: *Three known by 2009*

Pluto

Pluto, now classified as a dwarf planet, was named after the mythological god of the underworld. It was discovered by Clyde Tombaugh in 1930 and we still know very little about it. It was originally thought to be as big as the Earth and so was called a planet for many years. It is too far away to see in detail with a telescope. The first space probe intended to explore it was launched in 2006.

Pluto has one large moon, called Charon, which is about half the size of its parent body, Pluto. Some astronomers call Pluto and Charon a double dwarf planet because they are so close in size. In addition, two small moons were discovered in 2005.

Pluto has an unusual orbit around the Sun. It usually is further from the Sun than Neptune, but once every 248 years Pluto swings inside the orbit of Neptune. It stays there for 20 years. During this time, Pluto is closer to the Sun than Neptune.

While it is closer to the Sun, scientists think that Pluto might develop an atmosphere. They reason that methane and nitrogen frozen at its poles will thaw out and rise temporarily to form the atmosphere. But when Pluto moves back further from the Sun, they think its atmosphere will freeze again.

Moon fact file

Diameter: 3 476 km
Mean distance from Earth: 380 000 km
Day/night: 29.5 Earth days
Temperature: -170°C; maximum: 110°C

Moon

The Moon is the Earth's satellite. It is a rocky body orbiting our planet at a mean distance of 384 000 kilometres. Like the planets, it produces no light of its own, but we can see it because it reflects the light from the Sun. The shape that we see depends on where the Moon is in its orbit around the Earth. You can see the Moon clearly with the naked eye and even better with binoculars. You always see the same side of the Moon from Earth.

The Moon's surface has many craters, formed by large bodies such as comets and asteroids that crashed into it between 3 and 4 billion years ago. Apart from the craters, the Moon's surface is like a desert with plains, mountains and valleys. The Moon has no atmosphere, so there is no air to breathe, and no wind or weather. Recently, water ice was discovered at the poles of the Moon, buried beneath dust on the surface.

The Moon is the only place in our Solar System, other than the Earth, where humans have visited. On 20 July 1969 astronauts Neil Armstrong and Edwin Aldrin landed the Lunar Module of Apollo 11 on the Moon's surface. Armstrong became the first person to set foot on the Moon. A total of twelve astronauts landed on the Moon between 1969 and 1972. There are plans to develop new spacecraft so that humans can once again go to the Moon.

METEOROIDS AND METEORITES

Meteorites are rocks from space that strike the Earth.

Meteoroids are small stone or metallic rocks. Small ones form when comets (see below) come near the Sun. Small particles are thrown out by the comet by the million. They travel in the comet's orbit in huge swarms, but are invisible themselves. Large meteoroids come from the asteroid belt.

When a meteoroid enters the Earth's atmosphere it is travelling very fast. It will heat up and burn brightly. It is then called a meteor. We commonly call the streak of light it produces a "shooting star". A big meteoroid will produce a fireball.

Most of the original meteor will burn up before it strikes the surface of the Earth. Any meteor large enough to travel through the Earth's atmosphere and hit the ground is called a meteorite.

Ordinary meteors burn up at a height of about 50 km from the Earth's surface. Larger ones (bigger than a small stone) may explode, and pieces may land on the Earth as meteorites.

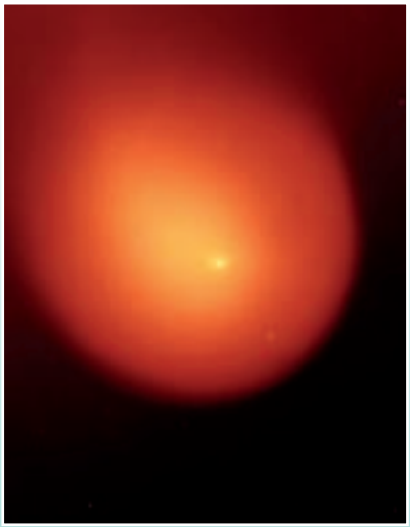
COMETS

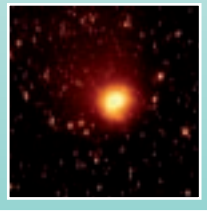
Comets are lumps of ice and rock that travel from the far outer Solar System to orbit our Sun. As the comet nears the Sun, the ice melts and gives off gas jets and clouds of dust. We see this as a dramatic tail, shining in reflected sunlight. Such a tail can stretch for many millions of kilometres.

A comet's tail (rock particles and melting ice) is forced away from its nucleus by solar winds. The tail of the comet can therefore be either behind or in front of it, depending on its position in relation to the Sun. A comet's tail always points away from the Sun.

Some comets take thousands of years to go around the Sun, while others take only a few years. Probably the most famous comet of all is Halley, which returns every 76 years.

Comets are usually named after the person who discovers them. Halley's Comet was named after Edmund Halley (1656 - 1742), an English scientist.





STARS

Stars are shining balls of gas. Their heat comes from deep inside, where hydrogen gas is turned into helium, giving out energy. Our Sun is the star we know best. Stars like the Sun have a relatively low mass. They shine steadily for billions of years before they burn out.

A star is formed when part of a cloud of gas and dust collapses. When the gas cloud draws itself into a dense blob, the temperature in the centre rises to millions of degrees Centigrade. At these temperatures, a nuclear reaction starts which gives off light … and a star is born, often with new planets orbiting around it. By April 2009, almost 350 planets had been discovered around other nearby stars.

When a star burns out, its central core collapses, shrinking down to the size of the Earth and it becomes a "white dwarf" star. One teaspoon of white dwarf material weighs as much as 5 tons! As its core collapses, the star's outer layers will expand and will finally be expelled in a very fast stellar wind, forming a beautiful planetary nebula.

Some stars can be up to 100 times as massive as the Sun, with much shorter lives, measured in millions of years.

Stars vary in temperature, brightness and size. Some are very hot and shine with a bluish light, while others are much cooler and look orange or red. These colours can be seen with the naked eye in some stars. Our Sun is an average star, slightly yellow in colour.

The brightness of a star as we see it depends on the type of star as well as its distance from the Earth. The brightest star in the sky is not the closest one to us. It is called Sirius and is much whiter and hotter than the Sun. The closest star to us after the Sun is called Proxima Centauri. It is small, dim and red. The astronomer Robert Innes discovered it from Johannesburg in 1915. It is the closest star to Earth (after our Sun).

A Hubble Space Telescope image of the very stunning planetary nebula called the Cat-Eye Nebula (NGC6543). The dying central star possibly produced this simple, outer pattern of dusty concentric shells by ejecting its outer layers in a series of regular convulsions. The formation of the beautiful, more complex inner structures is not well understood though.

Credit: NASA, ESA, HEIC, and The Hubble Heritage Team cI/AURA). Taken from Astronomy Picture of the Day.

Black holes

When a massive star dies, it explodes as a "supernova" which can be bright enough to see during the day. Many leave behind a core a little more massive than the Sun, that collapses down into a neutron star - the smallest, densest of stars, only about 30 km in diameter. One pinhead of such neutron star material would weigh about one million tons!

If the collapsing core is massive enough, its gravity becomes so strong that no light can escape from it, producing a "black hole".

GALAXIES

Galaxies are a collection of gas, dust and a vast number of stars. They are generally either spiral, round like a soccer ball, elliptical like a rugby ball, or irregular in shape. Dwarf galaxies may contain a few million stars and giant galaxies can contain billions of stars.

Our Sun is one of the stars in the Milky Way galaxy. The Milky Way, a spiral galaxy, is made up of over 100 billion stars. On a clear, dark night you can see the Milky Way. It looks like a hazy band across the sky. The hazy light is actually from billions of stars so far away that to our eyes their light blurs together. Telescopes however, show that it really is stars producing the light.

The Andromeda galaxy is the nearest major galaxy to our own Milky Way galaxy. They are similar in size and shape, and both have a number of dwarf galaxies orbiting them.

Galaxies often exist in groups. Our galaxy belongs to a group of galaxies called the Local Group. Astronomers have discovered many thousands of other groups of galaxies in the Universe.

THE UNIVERSE

People used to believe that the Earth was the centre of the Universe with everything else revolving around it. Now we know our planet is only one part of one small system. Our Sun is just one of billions of stars in our galaxy. Our galaxy and countless others like it make up the Universe.

The Universe is changing and getting bigger all the time. The American astronomer Edwin Hubble (1889 - 1953) was the first to discover that the galaxies are moving away from each other. He also discovered that the farther away a galaxy is, the faster it seems to be moving. The explanation for this is that space itself is expanding.

If space is expanding, it means that everything in space must once have been squashed together in a small, incredibly dense ball. Astronomers believe this ball started expanding about 14 000 million years ago, in what they call the Big Bang. This marked the beginning of the Universe as we know it.

Cosmology is the study of how the Universe began and how it will be in future. The Universe may go on getting bigger for ever. But it is also possible that the galaxies may come together and draw back into one place until they collide and rush together into the "Big Crunch". Scientists will continue to discuss this topic for many years.

SPACE EXPLORATION

For many centuries, space exploration seemed like a fantastic dream. To leave the Earth behind one has to build an engine powerful enough to travel at 11 kilometres per second. This is the speed that beats the pull of the Earth's gravity. In the twentieth century, the invention of powerful rockets made space travel possible.

A man-made satellite is a spacecraft placed in orbit around a planet. Thousands of satellites have been launched and are currently in orbit around the Earth, where they gather information about the Earth and the Universe.

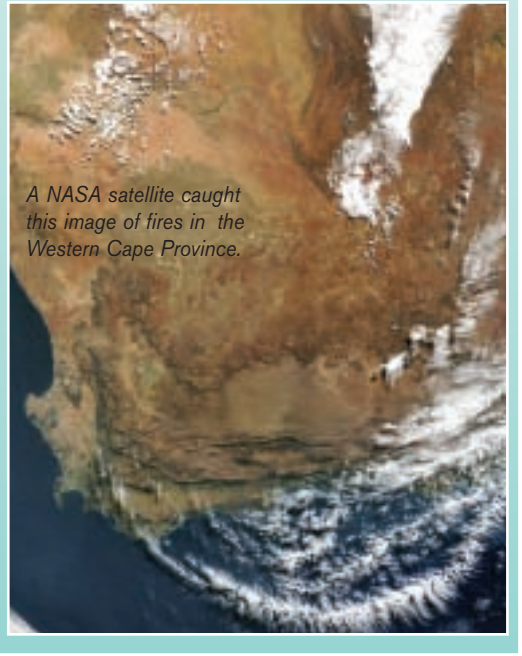
USES OF SATELLITES

Satellites are launched into space to do a specific job. Some examples:

- ★ Remote sensing satellites carry cameras that take pictures of the Earth.
- ★ Weather satellites take pictures to help experts predict weather patterns and their movements.
- ★ Navigation satellites carry special transmitters to help people work out exactly where they are.
- ★ Communication satellites bounce messages such as telephone calls, television images and Internet information from one side of the world to the other.
- ★ Space tourism satellites transport, transfer and care for people who want to holiday in space. This is a relatively new idea and only affordable to the super rich.
- ★ Military satellites are used for spying or to guide missiles.

(Information kindly supplied by the CSIR Satellite Application Centre)

The launch of a Soyuz rocket into space.



A NASA satellite caught this image of fires in the Western Cape Province.

SPACE EXPLORATION FACT FILE

- ★ Rocket-propelled spacecraft were first seriously studied by a Russian, Konstantin Tsiolkovsky (1857 - 1935).
- ★ Herman Oberth (1894 - 1989) experimented in Germany with small solid-fuel rockets.
- ★ The first rocket to use liquid fuel was built in 1926 by the American, Robert H. Goddard.
- ★ 4 October 1957: the Soviet Union (Russia) began the age of space exploration with the launch of Sputnik 1, the first artificial satellite. Sputnik orbited the Earth in 90 minutes and stayed in space for six months.
- ★ Sputnik 2 (USSR, 1957) launched the first living creature into space – a dog called Laika, who spent a week in orbit.
- ★ Explorer 1 (USA, 1958) was the USA's first successful satellite.
- ★ Telstar 1 was the first communications satellite. Launched in 1962, it carried one television channel. Live television images could be sent to Europe from the USA for the first time.
- ★ 12 April 1961: Yuri Gagarin (USSR) became the first man in space.
- ★ 5 May 1961: Alan Shepard becomes the first American to travel in space.
- ★ Mariner 2 (USA) was the first successful probe to visit a planet. It flew past Venus on 14 December 1962 and made temperature measurements.
- ★ 16 June 1963: Valentina Tereshkova (USSR) became the first women in space.
- ★ 8 March 1965: The first spacewalk takes place (Alexei Leonov, USSR).
- ★ In 1966, Luna 9 (USSR) becomes the first spacecraft to make a soft landing on the Moon and return pictures of the Moon's surface.
- ★ The first manned flight around the Moon takes place in December 1968 (Apollo 8, USA).
- ★ 20 July, 1969: The first Moon landing takes place (Apollo 11, USA).
- ★ The Russian Salyut 1 became the first space station when it was put in orbit in 1971.
- ★ 20 July 1976: The US probe, Viking 1, becomes the first to land successfully on Mars.
- ★ First successful flybys of Jupiter and Saturn by the space probes Pioneer 10 and 11 in 1973 and 1979.
- ★ In 1977 space probes called Voyager I and Voyager II were launched. Their missions were to reach Jupiter, Saturn, Uranus and Neptune and send pictures back to Earth. By now (2010) Voyager I has travelled 170 billion km and shows signs of nearing the edges of the Solar System.
- ★ 12 April 1981: The first launch of the reusable spacecraft, Space Shuttle (Columbia, USA).
- ★ 24 April 1990: The Hubble Space Telescope is launched on board the space shuttle Discovery.
- ★ 2 November 2000: The first crew to stay aboard the International Space Station arrives.
- ★ July-Sep 1997: Mars Pathfinder, the first Mars rover, explores the surface of Mars.
- ★ 12 February 2001: Spacecraft NEAR soft lands on asteroid Eros after studying it from orbit.
- ★ January 2004: Two Mars rovers, Spirit and Opportunity, land on Mars. Both are still working in 2010.
- ★ 1 July 2004: Spacecraft Cassini enters orbit around Saturn to study the planet, its rings and moons, after a six year journey from Earth.
- ★ 14 January 2005: Cassini's probe Huygens soft lands on Titan - the first landing on the moon of another planet.
- ★ New Horizons mission launch on 16 January 2006; its aim is to reach and study Pluto and its companion Charon. It is expected the space probe will reach its destination in 2015.

SOUTH AFRICA AND SPACE EXPLORATION

From the late 1950s to the 1970s South Africa operated spacecraft tracking stations for NASA. Deep Space Station 51 at Hartebeesthoek later became the Hartebeesthoek Radio Astronomy Observatory, while the STADAN site nearby became the CSIR's Satellite Application Centre.

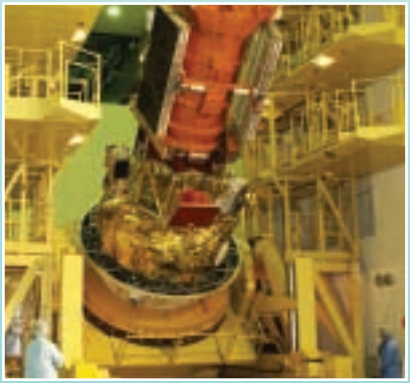
Two South Africans have been into space. IT millionaire Mark Shuttleworth from Cape Town spent a week as a "space tourist" in the International Space Station (ISS). He was launched into space in a Russian Soyuz three-person space capsule from the Baikonur cosmodrome on 25 April 2002. Launching people into space is very expensive, so it was always government funded. However, modern technology has brought down costs, and private companies are now developing manned space travel. The first privately built space-ship was Spaceship One, designed by Burt Rutan. The pilot who first took it all the way into space – higher than 100km above the ground – on a test flight on 21 June 2004 was Mike Melvill, who comes from Durban. SpaceShipOne can now be seen in the National Air and Space Museum in Washington D.C.

South Africa has also built two space satellites. The first, called Sunsat, was built by Stellenbosch University. It was launched on an American rocket in 1999. It operated for about a year. The second, called SumbandilaSat, was launched on 17 September 2009 on a Russian rocket. It was built by Sun Space and Information Systems in Stellenbosch. Sumbandila, meaning "lead the way" in the Venda language, will carry powerful cameras onboard, able to distinguish objects as small as 6.25 m from its 500 km orbit above the Earth.

South Africa has now formed its own Space Agency to promote the peaceful uses of space. Would YOU like to go into space?

Mike Melvill on Space Ship One.

Mark Shuttleworth in space.



The Fregat Upper Stage of the Soyuz Rocket with all payloads fully integrated onto it. The huge orange coated satellite is the Meteor M-1 and SumbandilaSat is the tiny black square on the left.

FAMOUS ASTRONOMERS

Anaximander (611-547 B.C., Ionian) was a Greek philosopher who made the first detailed maps of the Earth and the sky. He knew that the Earth was round, and believed that it was free-floating and unsupported. He measured its circumference, and was the first to put forward the idea that celestial bodies make full circles in their orbits.

Aristotle (384-322 B.C., Greek), the great philosopher, proved that the Earth is spherical, and believed that it was at the centre of the Universe.

Aristarchus (310-230 B.C., Greek) was the first to believe that the Sun was in the centre of the Universe.

Hipparchus (190-120 B.C., Greek) is considered the greatest ancient astronomer. He compiled the first star catalogue and also came up with a scale to define the brightness of stars. A version of this scale is still used today. He discovered the precession, or slow rotation, of the direction of the Earth's axis, which is caused by the gravitational pull of the Sun and Moon.

al-Khwarizmi (780-850, Islamic) was the inventor of algebra. He performed detailed calculations of the positions of the Sun, Moon, and planets, and did a number of eclipse calculations.

Nicolaus Copernicus (1473-1543, Polish) began a new era of astronomy when he concluded that the Sun was the centre of the solar system instead of the Earth.

Galileo Galilei (1564-1642, Italian) is the father of observational astronomy. In 1609, he heard about the Dutch invention of the telescope, and built one for himself. He saw the craters, mountains, and valleys of the Moon, noticed the huge number of stars making up the Milky Way, kept precise records of sunspot activity and the phases of Venus, and discovered four moons orbiting Jupiter.

Johannes Kepler (1571-1630, German) used the idea of elliptical orbits to describe the motions of the planets.

Giovanni Cassini (1625-1712, Italian) was the astronomer who first discovered the division in the rings of Saturn. He also found four moons orbiting Saturn, and measured the periods of rotation of Mars and Jupiter.

Isaac Newton (1643-1727, British) was a mathematician who described the astronomical models of Copernicus and Kepler. Newton showed that the laws governing astronomical bodies were the same laws governing motion on the surface of the Earth. Newton's scientific ideas still offer an accurate description of physics today, except for certain cases in which Einstein's Relativity Theory must be used.

Edmond Halley (1656-1742, British) became famous for predicting the 1682 appearance of a comet now named after him.

Arthur Eddington (1882-1944, British) lead an expedition in 1919 during a solar eclipse to prove Einstein's theory of general relativity was correct. He made the first direct measurements of stellar masses and discovered the link between the mass of a star and its energy output. He also correctly suggested that nuclear fusion was the primary source of energy in stars.

Edwin Hubble (1889-1953, American) discovered that faraway galaxies are moving away from us. This concept is a cornerstone of the Big Bang model of the universe.

Albert Einstein (1879-1955, German) was probably the greatest mind of the twentieth century. His Special Theory of Relativity was proposed in 1905. In 1915, Einstein extended this further in the General Theory of Relativity, which includes the effects of gravitation.

Stephen Hawking (1942-, British) is another brilliant mind of the twentieth century. He combined the theory of general relativity and quantum theory in order to prove that black holes emit radiation and eventually evaporate.

FAMOUS WOMEN ASTRONOMERS

Jocelyn Bell-Burnell (1943 –, British) discovered pulsars in 1967 as a PhD student at Cambridge University, while supervised by Antony Hewish (who received the Nobel Prize for the discovery).

Annie Jump Cannon (1863 – 1941, USA) was the first astronomer to classify the heavens systematically. She worked as an astronomer and published information about 225 000 stars.

Cecilia Payne-Gaposchkin (1900 – 1979, British). Her PhD dissertation, showing stars are made primarily of hydrogen and helium, was said to be one of the best in 20th century astronomy.

Henrietta Swan Leavitt (1868 – 1921, USA) discovered that a particular type of variable star known as a Cepheid could be used as a distance marker, making it possible to determine astronomical distances to objects such as far away galaxies.

Carolyn Shoemaker (1929 – , USA) had discovered 32 comets by 2002, more than any living astronomer. She has also discovered more than 300 asteroids.

Women Astronomers in South Africa

Women play a big role in astronomy in South Africa. Dr Patricia Whitelock of the South African Astronomical Observatory uses the variable Mira stars to establish distances. Dr Sharmila Goedhart of South Africa's KAT/SKA project is an expert on the formation of high-mass stars. Dr Claire Flanagan at the Johannesburg Planetarium studies neutron stars. Dr Catherine Cress at the University of the Western Cape is a cosmologist. Professor Renee Kraan-Korteweg heads the Astronomy Department at UCT and studies galaxies.

SOUTH AFRICAN ASTRONOMERS in History

South African astronomers have done exceptional work:

- ★ Sir John Herschel was not only an excellent observer but also a pioneer of photography as well as one of the fathers of education in South Africa.
- ★ Thomas Maclear's geodetic work led to the establishment of the Government Trigonometrical Survey Office of South Africa, the Meteorological Commission and the Commission of Standards for Weights and Measurements.
- ★ David Gill pioneered astronomical photography, designed the reversible transit circle.
- ★ Robert Innes showed that Proxima Centauri was the nearest star to the Sun. He was a brilliant self-taught mathematician and astronomer who left school at age 12 and became a Fellow of the Royal Astronomical Society when he was only 17.
- ★ Dr Bernie Fanaroff studied radio galaxies and has classes of galaxies named after him. He now leads the Karoo Array Telescope project.
- ★ Dr Thebe Medupe grew up near Mafikeng. He earned his MSc (cum laude) in Astrophysics, and then obtained his Astrophysics Doctorate at the University of Cape Town. He founded and leads the University of North West's theoretical astrophysics programme, and became a steering committee member of the National Astrophysics Space Science Programme in 2002.

These astronomers are just a small selection of the people who have enriched our astronomical heritage.

ASTRONOMY IN SOUTH AFRICA

History

South Africa has a rich heritage of ethno-astronomy and starlore within several of its many cultural groups.

Modern astronomy in South Africa begins with ships. Accurate positions for southern stars were simply not available to navigators, and the position of the African coastline wasn't very well known either. In 1685 a Frenchman, Father Guy Tachard, set up a small temporary observatory in the Cape. He and his assistants discovered that most of the stars shown on their charts of the extreme southern sky did not exist at the marked positions, while many others were omitted altogether. He also estimated (from observations of Jupiter's moons) that Cape Town was nearly 300 km west of its position on his maps of the Earth.

The first really important astronomer in South Africa was Nicholas de la Caille, who spent two years (1751-53) in the Cape. He charted the positions of almost 10 000 stars and measured the shape of the Earth.

In 1820, a permanent observatory was established outside Cape Town. It was headed by a brilliant young Cambridge mathematician, astronomer and clergyman, the Reverend Fearon Fallows. Two observers were often necessary to get results with the instruments of Fallows' day, but Fallows had great difficulty getting even one reliable assistant. As a result he often observed with his wife, Mary Ann. Her independent discovery of a comet in 1830 places her first on the roll of South African women observers in this field.

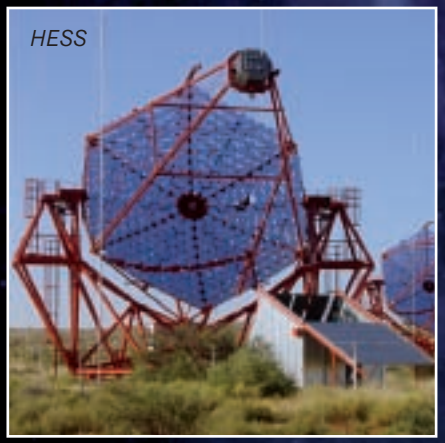
The history of the South African astronomy also has roots in other parts of the country. The Natal Observatory was founded in Durban at the time of the 1882 transit of Venus. The observatory was closed in 1911.

In 1903 the Transvaal Meteorological Department, from which the Republic Observatory in Johannesburg later developed, was created.

The present South African Astronomical Observatory (SAAO) was formed in 1972 by combining the Royal Observatory (Cape Town) with the Republic Observatory (Johannesburg). Its headquarters are in the old Royal Observatory buildings in Cape Town. The three most modern telescopes from the two observatories found a new home in the Karoo just outside the town of Sutherland. In 1974 the Radcliffe Observatory telescope at Pretoria was also moved to the Karoo. The Southern African Large Telescope (SALT – see page 25) is the latest addition to the telescopes at Sutherland.

The 0.5-m Telescope at the SAAO near Sutherland with the 0.75-m Telescope in the background.
Photo: Helga Nordhoff

SALT



HESS

Modern Times

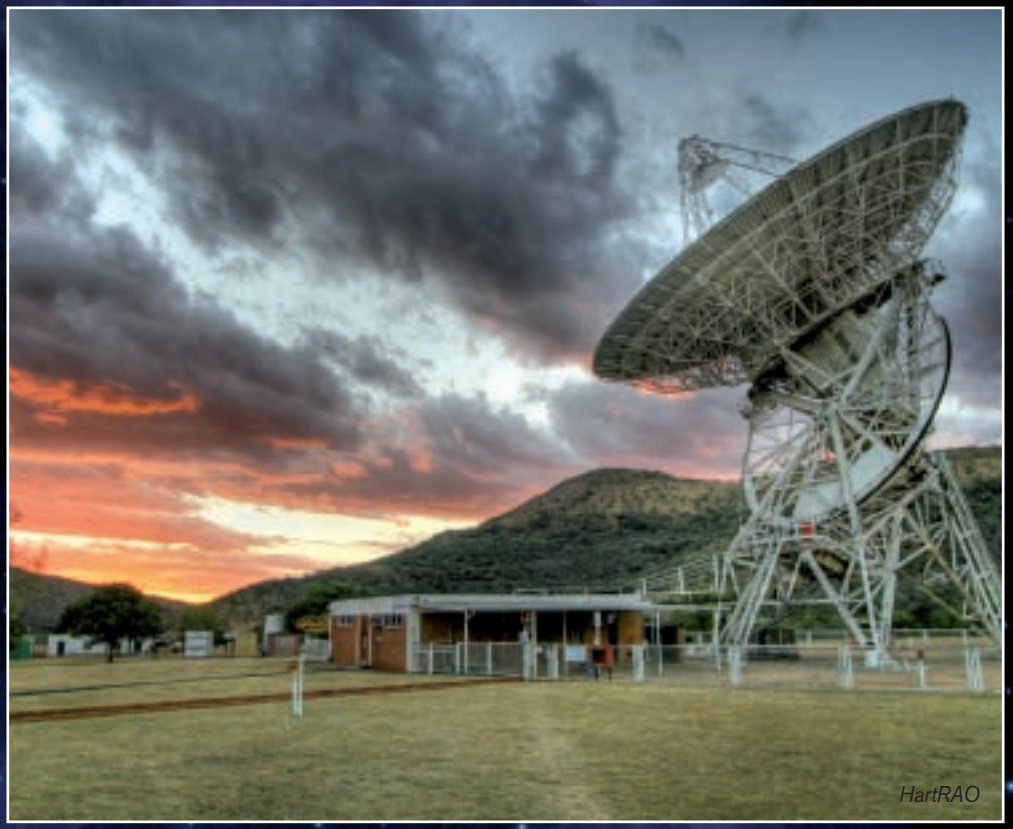
Since 1972, the SAAO has had the advantage of the dark, unpolluted skies of the Karoo, with no special 'cloudy season' when observing would be difficult. Research has concentrated on understanding the nature and life cycle of stars of various kinds. Galaxies, both the nearby Magellanic Clouds and the more distant galaxies are observed from Sutherland.

SAAO research has also contributed to understanding the centre of our own galaxy, using infrared cameras and detectors to pierce the thick dust clouds that hide the centre from view. A particular field of interest is the study of stars whose size and light vary.

In 1961 South Africa became a Republic and as a result of the policy of apartheid, sanctions were imposed. Most of the foreign institutions withdrew their support. South African institutions were financially hard-pressed to keep the observatories running. In 1994 South Africa held its landmark democratic elections and sanctions were withdrawn. The international astronomical community started to re-invest in South Africa's clear dark skies. The southern African region has become a premier destination for cutting-edge astronomy projects.

Boyden Observatory in Bloemfontein became operational again after a period of dormancy.

The most exciting post-sanction infusion into Southern African astronomy is the Southern African Large Telescope (SALT) project at Sutherland, which was opened in November 2005. South Africa's neighbours are also benefiting. In Namibia, the H.E.S.S. Gamma Ray Telescope is in operation. The H.E.S.S. team includes astronomers from North-West University in South Africa.



HartRAO

Radio Astronomy

In the late 1950s, tracking stations for man-made satellites were erected in South Africa. The Hartebeesthoek Radio Astronomy Observatory (HartRAO) near Krugersdorp had its origins in collaboration with the US Jet Propulsion Laboratory, and later NASA. The telescope was originally part of NASA's deep space network of telescopes responsible for supporting a number of early interplanetary and lunar missions. Recently there has been increasing interest in radio astronomy. HartRAO has the only radio telescope in Africa and is much in demand for international collaboration. HartRAO is assisting in the development of a new radio telescope in Nigeria.

HartRAO

An artist's impression of the completed SKA

Completed MeerKAT dishes

Above: MeerKAT Prototype

The Square Kilometre Array Radio Telescope

South Africa is currently bidding to host the largest ever radio telescope to be built by an international group of collaborators, the Square Kilometre Array (SKA). This radio telescope will be able to probe the secrets of the time the Universe was formed. Australia is the other country remaining in the competition to host the SKA.

To help develop the new technologies needed for the SKA, South Africa is building demonstrator telescopes. The first of these is called the eXperimental Development Model (XDM). It is 15 metres in diameter and was built at Hartebeesthoek in 2007. Currently under construction is the Karoo Array Telescope – 7 (KAT-7). This is a group of seven telescopes each 12 metres in diameter being built west of Carnarvon in the Northern Cape. It is expected that this will be followed by an array of dozens of similarly sized telescopes, called MeerKAT.

Space Geodesy

"Geodesy" means the measurement of the shape of the Earth. Space Geodesy in South Africa is a spinoff of radio astronomy at Hartebeesthoek. It started as part of a NASA programme to measure the present-day movement of the continents. The Hartebeesthoek 26 metre diameter radio telescope took part in this programme, starting in 1986. The telescope, which is attached to bedrock, was found to be moving North-East at 25mm per year. This 1992 result was the first measurement of the motion of the African continent, and has been confirmed by many years of measurements since then.

The radio telescope is the most accurately located point on the African continent. As a result, from 1998 its position has been used as the reference point for the survey system of South Africa, used for accurate position measurement. This replaced the old system which dated back to the 1880s, and in which the astronomers at the Cape Observatory (now SAAO) had been involved.

The Space Geodesy Programme in South Africa now also operates a NASA Satellite Laser Ranger (SLR). This uses a laser which fires high power pulses of light at satellites. Mirrors on the satellites reflect the light back to the SLR, which measures how long the round trip took. As the speed of light is known, the distance to the satellite is easy to calculate. This system can measure the orbits of satellites to an accuracy of a few centimetres.

In addition, Global Positioning System (GPS) receivers have been set up in several places in South Africa and in other Southern African countries, on Mauritius and Marion

Above: GPS Antenna

Island in the Indian Ocean and at the South African National Antarctic Expedition (SANAE) base in Antarctica, in order to measure their movements. Several are placed alongside tide gauges so that together they can accurately measure the change in sea level caused by global warming. GPS receivers work by comparing the signals received from a number of satellites in orbit overhead to calculate the position of the GPS receiver on the land.

Below: SLR Operator

Above: NASA Satellite Laser Ranger (SLR)

Right: GPS Satellite in Orbit